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Art. V.—*The Evidence of Post-Lower Carboniferous Plutonic and Hypabyssal Intrusions into the Grampian Sandstones of Western Victoria.*

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(Plates V. and VI.)

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Introduction.

The interest of the present communication lies in the definite establishment in Victoria of plutonic intrusions younger than the Lower Carboniferous period.

Apart from this area no plutonic rocks younger than Lower Devonian in age have hitherto been proved or suggested to exist in Victoria. In 1913 I spent a fortnight in geological examination of the Grampians region with Mr. Ferguson, of the Geological Survey of Victoria, and the present paper is based on field evidence obtained during that visit, supplemented by later petrological examination of the specimens then collected.

Previous Literature.

The literature dealing with the relations of the igneous rocks to the Grampian sandstone is included in the following papers:—

1. F. M. Krause, Progress Report of Geol. Survey of Victoria, No. 1, 1874, pp. 125-126 (with geological map and sections).
2. H. Herman, Special Reports Mines Dept. of Victoria, 1900, pp. 1-7 (with geological map and section.)
3. T. S. Hart. Proc. Roy. Soc. Vict., Vol. XX. (N.S.), Pt. 2, 1907 (issued 1908), p. 269.
4. E. J. Dunn. Records Geol. Surv. Vict., Vol. III., Pt. 2, 1912, p. 116 and p. 118.
5. W. H. Ferguson, Records Geol. Surv. Vict., Vol. IV., Pt. 1, 1917, pp. 5-9.

The evidence, as to the relations of the igneous rocks of the area to the Grampian sandstone, included in the above papers may be summarised as follows:—Krause expressed himself as doubtful of the relations, but published a geological section showing the granite as intrusive into the sandstone. H. Herman could find no evidence of intrusion, and quoted A. W. Howitt as identifying the plutonic igneous rock as "quartz-mica-diorite (L. Devonian?)." T. S. Hart evidently believed the plutonic rock to be older than the sandstone and thought the dykes in the sandstone were more probably allied to the Coleraine trachytes than to the granitic rocks.

E. J. Dunu stated that where the granite is first seen on the road from Hall's gap the beds of sandstone are altered to quartzite by contact metamorphism, showing the granite to be more recent than the Grampian sandstone. W. H. Ferguson stated that from general field evidence it appears that the granodiorite and porphyries are intrusive into the sandstone. This conclusion is based on the following evidence: —1. Near the granite rocks the sandstones are in many places altered into quartzites. 2. In some places small dykes appear to extend from the granodiorite into the sandstones. 3. True quartz veins in the sandstones have been noted only close to the contact of granodiorite or porphyry. 4. No conglomerate containing granite boulders or quartz derived from granite rocks was found at the base of the sandstones where they rest directly on the granodiorite.

Discussion of Previous Literature.

With reference to Mr. Hart's statement that the dykes in the sandstone are more closely related to the Coleraine trachytes than to the granitic rocks evidence will be quoted below showing that this view is incorrect and that the dykes are mineralogically and genetically related to the plutonic intrusions.

Mr. Dunn's communication gives the first positive statement of the intrusion of the granite into the sandstones, but the evidence cited viz., the presenc of quartzite along the contact, is, by itself, not convincing proof. The quartzites might be metasomatic in origin and due to deposition of silica from downward migrating solutions arrested in their movement through the sandstones by contact with the plutonic rock.

Mr. Ferguson's evidence is cumulative and fuller, and adds to the evidence of the quartzite the recognition of the limitation of the quartz veins to the contact zone, and the statement that small dykes "appear" to extend from the granodiorite into the sandstone. In addition he quotes the negative evidence of the absence of granitic conglomerates at the contact.

In view of the interest of the occurrence I wish to supplement the evidence published by Messrs. Dunn and Ferguson by my own observations in the field and by evidence based on microscopic examination of the rocks collected.

Field Evidence.

Evidence was obtained from the Mt. William goldfield in the south, from near the Wartook Reservoir in the north, and from near Hall's Gap in the central part of the area. Interest centres in two questions—(1) The nature of the contact of the sandstones with the plutonic rock and (2) the relations of the hypabyssal igneous rocks to the sandstones.

1. The contact of the sandstones with the plutonic rock.

(a) Mt. William goldfield. In the upper tunnel of the Coronation mine the plutonic rock occurs on the floor of the tunnel while sandstone or quartzite forms the roof for a considerable distance. The plutonic rock is decomposed but sends small igneous veins into the sandstone. (Sketch section a).

(b) Three miles from Wartook Reservoir towards Rosebrook. Here the contact of quartzite and plutonic rock runs along the road on a ridge. As Mr. Ferguson has stated, at this place a dyke occurs in the plutonic rock near the junction and another within the quartzite, which can be traced to within a few feet of the junction. The two dykes both in hand specimens and in section are petrologically identical. The sandstones near the junction are converted into quartzites, and an important additional piece of evidence of the intrusive character of the plutonic rock is yielded by the observation that the quartzites along the contact and for a few feet away from it are completely primsmatized and readily break up or weather into somewhat irregular but definite polygonal prisms. (Sketch plan and section b.)

2. The relations of the hypabyssal igneous rocks to the Grampian sandstones.

Mr. Ferguson has referred to the fact that many dykes cutting across the bedding of the sandstone are to be seen in various parts of the area while in other cases they appear to have been thrust into the sandstones along the bedding planes. It follows from this that both dykes and sills are present. This evidence is supported by my own observations, and it becomes of importance if it can be shown that these hypabyssal rocks are genetically related to the plutonic rocks. In the field going southwards along the mining tract, after crossing Stony Creek and just above Venus' Bath, the sandstones strike N.20°E. and dip W.20°N. at 27°. At this point there is a junction with a porphyrite which is here about 28′ thick. The igneous rock at first lies evenly between the bedding planes but further on it cuts across the beds of sandstone making an irregular junction. The rock is therefore not an interbedded flow but an intrusive rock, partly sill, partly dyke. (Sketch section c.) The sedimentary rocks immediately below the intrusion, however, are sandstones, while five chains along the road and above the intrusion the rocks are quartzites. This indicates the necessity of caution in using the presence or absence of quartzite near the igneous contact as evidence of intrusion or otherwise. Several porphyrite dykes occur further south on this road towards the Stony Creek dredge and gold workings. On the stairway to Mt. Rosea, as Mr. Ferguson has stated, a decomposed porphyrite dyke 5—10′ thick, occupies a fault plane cutting across the quartzite. (Sketch section d.) At the McKenzie Falls, three miles S.S.W. from Wartook Reservoir, the falls, which have a throw of about 100 feet, are caused by differential erosion between the sandstones which here dip N. 20° E. at 10° and a big vertical porphyrite dyke striking E. and W. and cutting across the sandstone. (Sketch section e.)

Microscopic Examination of Igneous and Sedimentary Rocks.[1]

Plutonic Types.

One analysis described as granite from Mt. William, near Stawell, from Ann. Rep. Mines Dept., Vic., 1900, p. 37, by H. C. Jenkins, is available. It is as follows:—SiO_2 = 66·86; Al_2O_3 = 14·91; Fe_2O_3 = 4·06; FeO = 3·65; MnO = tr; CaO = 3·25 MgO = 1·28; Na_2O = 4·22; K_2O = 1·49; H_2O + = 0·9; H_2O — = 0·58. Total = 100·39.

This analysis, together with the great abundance of plagioclase in the rocks, indicates that they can be appropriately described as granodiorites.

No. 1254. Fresh porphyritic hornblende grano-diorite. Coronation tunnel, Mt. William. (Plate I. Fig. 1.)

Green hornblende is abundant, a little brown biotite occurs, abundant zoned plagioclase, probably andesine and large quartz crystals. A later crop of small quartz crystals included in and intergrown with smaller felspar crystals gives the appearance of a coarse ground mass. Accessory minerals include ilmenite, sphene, zircon, and calcite.

No. 1255. Porphyritic hornblende grano-diorite, 300 yards N.W. of dredge, Stony Creek.

The minerals present are similar to those in No. 1254, but chlorite and epidote occur and the plagioclase is in part cloudy. The rock is rather finer in grain and the holocrystalline ground mass of smaller quartz and felspars rather more prominent.

No. 1266. Porphyritic hornblende biotite grano-diorite, Wannon Valley, three miles below Mafeking.

The mineral content is similar to the previously described rocks, much of the plagioclase is cloudy and biotite is more abundant than in Nos. 1254 and 1255.

Hypabyssal Types.

No. 1253. Microspherulitic quartz porphyrite dyke, Wartook dam.

Phenocrysts of zoned and partially corroded andesine and corroded quartz are set in a ground mass in part microspherulitic in texture, consisting of laths of plagioclase, sometimes radially arranged, of which some are clear and others cloudy, interstitial quartz, ragged, minute crystals of biotite more or less altered to green chlorite, opaque crystals of ilmenite altering to leucoxene, and a little epidote and zircon.

No. 1262. Quartz felspar porphyrite, Broken Falls, McKenzie's Creek.

Large porphyritic cloudy crystals of plagioclase and corroded and embayed crystals of quartz with large green chlorite, after biotite are set in a microcrystalline matrix of cloudy felspar and of quartz with

1 The numbers of the specimens are those of rock sections in the collection of the University of Melbourne.

fairly abundant ilmenite. Small irregular areas of purple and of colourless fluorspar are also present.

No. 1256. Hornblende porphyrite, road above Venus' Bath, Hall's Gap.

Hornblende, altered to chlorite and a carbonate, and plagioclase, cloudy through alteration, occur as phenocrysts. The microcrystalline ground mass consists mainly of quartz and cloudy felspar. In addition there are present ilmenite, a carbonate and epidote.

No. 1264. Microspherulitic quartz felspar porphyrite dyke in sandstone near granodiorite, three miles from Wartook.

Phenocrysts of clear and partially cloudy plagioclase and of corroded quartz in a matrix, partly microcrystalline to micrographic and partly microspherulitic, of quartz and felspar with subordinate biotite sphene and needle-shaped apatite.

No. 1265. Microspherulitic quartz felspar porphyrite vertical dyke at big falls near Wartook. (Plate V. Fig. 2.)

Phenocrysts of plagioclase, corroded quartz and biotite and hornblende, the two latter altered to chlorite and epidote set in a micrographic to microspherulitic matrix of quartz and felspar with some ilmenite, zircon and epidote.

Dyke and Sandstone Contact.

No. 1263. Quartz felspar porphyrite in contact with quartzite, at McKenzie Falls.

The dyke consists of phenocrysts of plagioclase and quartz in a silicified ground mass consisting mainly of microscopic microspherulitic aggregates of chalcedony with negative elongation of fibres. The quartzite consists mainly of quartz grains with few felspar grains, which are partly interlocking but which are mainly set in a ground mass of secondary quartz aggregates indicating the conversion of a sandstone into a quartzite.

Sandstones.

Sandstones from building stone quarry, North of Hall's Gap.

The principal constituent consists of rounded and subangular clastic quartz fragments, a few rounded, clastic grains of tourmaline and a few felspar fragments with a small amount of definite matrix, probably partly felspathic, partly siliceous. The rock is a typical unaltered sandstone.

This rock is to be contrasted with sandstones altered to quartzites at or near the contact with porphyritic granodiorite at Coronation Tunnel, near the dredge in Stony Creek, and from a locality about three miles S.W. of Wartook Reservoir.

Quartzites.

No. 1258. Prismatized quartzite at contact with plutonic rock about three miles from Wartook Reservoir.

The rock is a quartzite consisting of relatively large and closely interlocking crystals of quartz with a subordinate amount of ironstained felspathic (?) interstitial matter. No rounded, clastic boundaries remain and abundant microscopic inclusions or bubbles pass across the boundaries of the interlocking quartz crystals.

No. 1260. Quartzite at contact with plutonic rock, 250 yards N.N.E. of dredge in Stony Creek.

A quartzite with large interlocking quartz crystals and abundant strings of linear inclusions passing across the boundaries of the crystals. Very minute rounded prismatic secondary brown and blue tourmalines are included in the quartz crystals. A little secondary white mica is also present.

No. 1259. Felspathic quartzite from Pincombe's shaft, Coronation tunnel, Mt. William.

A quartzite with coarse-grained interlocking quartz crystals and fairly abundant kaolinized felspar and secondary white mica. Minute rounded bulbs of felspar or glass are included in the larger crystals.

Summary of Field and Microscopic Evidence.

The field evidence quoted above shows that the granodiorite in places sends veins into the sandstones, that the sandstones in contact with the granodiorite are not only converted into quartzite but that in some cases the latter are definitely prismatized. Further, dykes of similar character occur both in the plutonic rock and also cutting the sandstones a few feet away from the contact. Among the hypabyssal rocks both dykes and sills are represented, but the alteration effected by these on the sandstone is capricious, being in places notable and in others negligible.

The microscopic evidence shows that a very close resemblance in mineral composition can be traced between the plutonic and the hypabyssal types since hornblende, andesine, biotite and quartz occur in nearly all the types examined. There can be no doubt, therefore, that both the plutonic and bypabyssal rocks were derived from a common magma and belong to the same geological period of igneous activity. Further proof of the intrusive character of the plutonic rock is yielded by the evidence that the alteration of the sandstones to quartzite at the contact is of the contact metamorphic and not of the metasomatic type. This is established by the almost complete interlocking of the crystals, the general absence of a secondary quartz matrix, by the presence of secondary non-clastic tourmaline, of secondary white mica, by the occurence of blebs of glass or felspar in the quartz crystals and by the linear arrangement of inclusions or of bubbles passing through the interlocking quartz crystals. The field and microscopic evidence, therefore, conclusively demonstrates the intrusive character of the plutonic rocks as well as of the hypabyssal sills and dykes of the Grampians region. The age of the Grampian sandstone on the available fossil evidence is stated to be Lower Carboniferous. The plutonic rock, with its associated dykes and sills is, therefore, clearly of post-Lower Carboniferous age.

The Relation of the Granodiorite and of the Hypabyssal Rocks to Earth Movements in Victoria.

It has hitherto been accepted that no marked fold movements have occurred in Victoria later than the Lower Devonian period since in general the Silurian sediments are the youngest to show widespread, and sometimes acute, folding, while the Middle and Upper Devonian sediments, often tilted to a high angle by faulting, are not known to be closely folded. At Buchan, in Eastern Victoria, however, the Middle Devonian limestones locally show well-defined and fairly acute anticlines while normally the dips are fairly low. The general association of plutonic intrusions with mountain making movements and with folding by compression raises the question, now that the granitic rocks of the Grampians are shown to be younger than the Lower Carboniferous, as to whether later fold movements, of a less severe character perhaps, may not have occurred in Victoria. Such later movements are well known in Northern New South Wales and in Queensland, but have not hitherto been recognised in Victoria. The available evidence is as yet too scanty for any but tentative suggestions. It may be, however, that the preservation of the Lower Carboniferous sandstones in Western Victoria is to be associated with broad geosynclinal down-warping with accompanying faulting in that region closely following the period of their deposition. In this connection it is to be noted that Krause[1] refers to the general synclinal structure of the Grampian sandstones about a meridional axis situated just at the western foot of the Victoria Range, while the older Palaeozoic rocks exposed in the area have also a suggestion of synclinal structure complicated by faulting, for high easterly dips occur in the western part of the area and high westerly dips in the eastern part of the area. The broad geosyncline of the Grampians sandstone is also affected by strike faulting[2]. Although the present physiographic features of the area are geologically more recent and probably in great measure controlled by the late Kainozoic movements of differential uplift, these are superimposed upon earlier structures. It may well be that the formation of the main geosyncline occurred during the Middle to Upper Carboniferous periods since rocks older than this period shared in the movements while younger rocks, such as the Permo-Carboniferous or late Carboniferous glacials, appear to occur in Victoria as unconformable plasters with very low dips, except where, as in part of the Bacchus Marsh district, they have been tilted in the neighbourhood of late Kainozoic faults.

We may tentatively conclude that, closely following on the probably Middle or Upper Carboniferous period of geosynclinal down-warping in Western Victoria, there was an uprising of magma from beneath the geosyncline which, penetrating through tension cracks in the sandstones, consolidated as porphyrite dykes and sills in the sandstones, while the bulk of the rising magma consolidated slowly

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1. Op cit. supra., p.p. 125-126.
2. T. S. Hart, op. cit. supra.

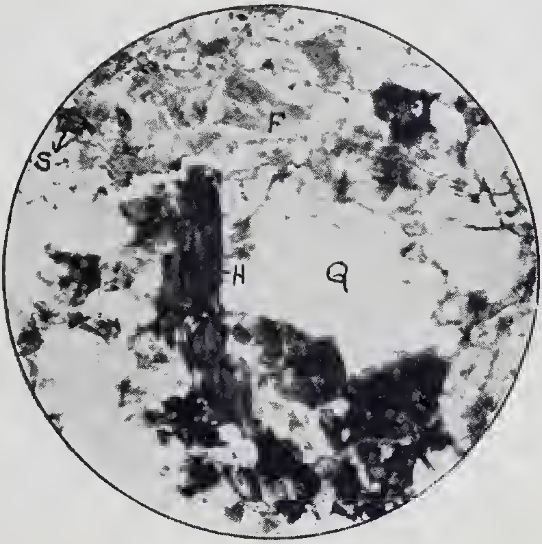

FIG. 1. × 23 diams.

FIG. 2. × 23 diams.